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Investigation of Chloride Migration in Reinforced Concrete under Application of Cathodic Protection

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Abstract:	Corrosion of reinforced concrete bridge structures in Ontario is a serious problem. Cathodic protection is a recognized way to control this corrosion and a number of bridges in the province now have these systems in place. This project was initiated to examine the mobility of the chloride ion in concrete under cathodic protection and to discover whether long term application reduces the chloride ion content in the concrete surrounding the reinforcing steel. The effect of power interrptions in these systems, the rate of recovery from them, and the possibility that a minimal current density could maintain an established cathodic protection system were other factors examined. The study found evidence of chloride migration in reinforced concrete slabs under cathodic protection at an elevated current density of 50 mA/m^2. For concrete protected at a more typical current density of 10mA/m^2, no chloride movement was detected over the duration of the tests (469 days). It was estimated that approximately 4% of the current flowing through a system under cathodic protection was transported by chloride ions. Upon removal of the cathodic protection from a slab in which a chloride concentration profile was well characterized and which increased with distance from the rebar, it was found that a significant amount of chloride ions migrated back toward the rebar over a six month period. Similarly, upon reduction of cathodic protection current density from 50mA/m^2 to 1 mA/m^2, the same effect was observed.
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A. Background:

Corrosion of bridge structures in Ontario is a serious problem that is associated with the intrusion into the concrete structure of chloride applied to the roadway in the winter months. Cathodic protection is a recognized way to control corrosion and a number of bridges in the Province now have such systems in place. However, little is known about the mobility of chloride ion in these systems and whether long term application of cathodic protection reduces the chloride ion content in the concrete surrounding the reinforcing steel. The effect of power interruptions in these systems, the rate of recovery from a power interruption, and the possibility that a minimal current density can maintain an established cathodic protection system are factors whose significance is unknown.

If the protection system maintains a net current through the concrete electrolyte, reduction will take place at the reinforcing rod cathode and corrosion will be inhibited. The two reduction reactions which may occur are as follows with production of hydrogen gas expected only at high current density:

$$2H_2O + O_2 + 4e \longrightarrow 4OH^-$$

$$2H_2O + 2e \longrightarrow 2OH^- + H_2$$

Corrosion inhibition is likely due to some combination of a shift of the potential of the rod to more negative values and a movement of chloride ion away from the cathode with an accompanying decrease in the chloride activity at the surface of the reinforcing rod. With a current flow, movement of chloride ion away from the cathode is to be expected since there are few other potential mobile charge carrying species in the concrete. Movement and depletion of the chloride at the cathode would be enhanced by increased current density and concommitantly this would result in an increase in the amount of reduction

products formed at the cathode. It is likely that some minimum applied current density may result in movement of chloride away from the reinforcing steel to give corrosion inhibition without significant electrolysis. At the anode of the protection system, a net current flow would produce oxidation products, with the nature of the products dependent upon the current density and the nature of the anode. Likely candidates are oxidation of chloride ion with liberation of chlorine, or oxidation of water with evolution of oxygen:

$$2Cl^- \longrightarrow Cl_2 + 2e$$

$$2H_2O \longrightarrow O_2 + 4H^+ + 4e$$

The chloride concentration gradient established in the matrix would be dependent upon the involvement of chloride in the electrode reactions.

Firstly, if chloride is not consumed at the anode, electrical transport would operate to move mobile chloride ions with depletion adjacent to the cathode and accumulation next to the anode. A concentration gradient would be established but ultimately back diffusion down this concentration gradient would oppose electrical transport and net transport of chloride would become zero. At this point any remaining current must involve mobile charge carriers other than chloride. The net result would be that a chloride concentration profile would be established which would not change with time.

In a second case, chloride may be consumed at the anode and this process would result in establishment of a time dependent concentration profile operating in concert with electrical transport. If the current is maintained there would be an increasing depletion of chloride from the system.

B. Objectives

a) To determine the mobility of the chloride ion in a system under cathodic protection.

b) To determine chloride concentration profiles in a series of mortar and concrete slabs under cathodic protection at current densities of 10 and 50 mA m^{-2} as a function of time.

c) To determine the rate of depletion of chloride ion and the percentage of current carried by the chloride ions in these slabs.

d) To examine the effect of power interruption or a reduced level of cathodic protection upon a system with an established chloride concentration profile.

C. Conclusions

a) Chloride ion was found to migrate in a slab under cathodic protection using a current density of 50 mA m^{-2}; for the normally used current density of 10 mA m^{-2} no chloride ion movement was detected over the time period of 469 days.

b) It was estimated that approximately 4% of the current flowing through a system under cathodic protection with a current density of 50 mA m^{-2} was transported by chloride ions. Under these conditions it can be estimated that using a current density at 10 mA m^{-2}, it would take over three years for there to be a statistically significant change in the chloride concentration in the slab.

c) Upon removal of the cathodic protection from a slab in which a chloride concentration profile was well characterized and which increased with distance from the rebar, it was found that a significant amount of chloride ion migrated back towards the rebar over a 6 month period.

d) Upon reduction of cathodic protection from 50 mA m^{-2} to 1 mA m^{-2} in a slab in which a chloride concentration profile was well characterized and which increased with distance from the rebar, it was found that a significant amount of chloride ion migrated back towards the rebar over a 6 month period.

e) A black deposit was found on the upper sides of rebars in which a current density of 50 mA m^{-2} had been employed.

D. Experimental

a) Mortar and Concrete Slab Preparation

Concrete and mortar slabs measuring 30 x 30 x 10 cm^3 were used for this study; concrete was the preferred substrate but because the aggregate introduced difficulties in obtaining representative samples for analysis mortar was also used. The slabs were constructed in the Civil Engineering Department under the supervision of Dr. B. Hope as follows: a 4 cm layer of concrete or mortar without added chloride was poured and three standard bars placed at equal spacing on top of it. The bars protruded from the slab for electrical connections. A second 6 cm layer of concrete or mortar containing 0.25-0.40%. Chloride by weight was then added to complete the slab. This produced a slab with a lower layer without added chloride and a chloride containing upper layer with the reinforcing rods located at the interface. The junction of the two layers was expected to be somewhat diffuse due to mixing and diffusion across the interface. Figures 1 a-c show the slabs and power supplies used in the experiments.

Forty-two mortar and concrete slabs were prepared in five batches as given in Table 1. After curing for 28 days the side surfaces of the slabs were sealed with epoxy paint. They were then coated with two layers of a conductive paint used for concrete cathodic protection and a platinum coated wire fixed across the surface by means of epoxy glue and a conductive grout to complete the anode. The slabs were then divided into six sets of six slabs each for further experimentation. Two sets of concrete slabs (AC1, BC2) and two sets of mortar slabs (CM3, DM5) were placed in a closed chamber with controlled humidity (room temperature, >90% relative humidity) and chloride migration within these slabs was studied

under these conditions. One set of concrete slabs (EC1, EC2) and one set of mortar slabs (FM4) were used for chloride migration experiments under exposed outdoor conditions. The remainder of the slabs were reserved for trial experiments and controls in the controlled humidity chamber.

In addition to the slabs, 4 inch diameter x 8 inch test cylinders were prepared from each batch of concrete and mortar used in the slabs and were numbered according to Table 2. These cylinders were analyzed for chloride and the levels compared to those in the slabs.

b) Connection and Maintenance of Cathodic Protection

Initial chloride concentration profiles for each of the five batches of concrete and mortar were determined in the slabs before connection to cathodic protection systems. Each set of six slabs were then connected in series to a rectified full wave, unfiltered power supply (see Figure 1). Connection was made on October 1 and 2, 1984 to the slabs in the constant humidity chamber and March 25, 1985 to those at the outdoor location.

For the slabs in the constant humidity chamber, a current of 0.9 mA (10 mA m^{-2}) was maintained for BC2 and DM5 and a current of 4.5 mA (50 mA m^{-2}) for AC1 and CM3. In addition, a further slab MS-17 maintained at a current density of 20 mA (222 mA m^{-2}) was connected on January 17, 1985. Control of the current at an appropriate value was by regulation of the input AC voltage of the power supply using an autotransformer. The power supplies were designed to provide up to 150 V DC to a set of slabs. The indoor experiments were begun after conditioning the slabs at a high constant relative humidity but the voltage required to produce the desired current was found to be relatively high and to increase with time. It was found that the voltage requirement could be reduced by covering the anode surface of each slab with a moist sponge. The sponges were introduced on 10 December, 1984 and covered the entire upper surface of the slab. They were moistened every two weeks and kept on the slabs for the duration of the work.

The slabs that were placed in the outside environment were controlled by power supplies, similar to those used by the Ontario Ministry of Transportation and Communications (OMTC), for the field protection of bridge structures but were modified for use. The basic units were Technisonic Industries Limited (TIL) DN 791150-1 Cathodic Protection

Regulated Power Supplies. The units, as normally supplied, provide up to 12 A at 16 V DC. The power supply and output current control of the units were modified to give reduced current levels with output voltages up to 110 V DC. The two sets of 6 slabs in the outdoor experiments were connected with cathodic protection at a nominal 0.9 mA (10 mA m^{-2}). It was found that the output voltage necessary to maintain the desired current through the slabs was very much a factor of the outdoor conditions. Cold and dry conditions required a large driving voltage and it was not possible, under some conditions, to maintain the current even with the full output voltage of the power supply (18 V / slab). While the control of the cathodic polarization current was as desired under relatively moist outdoor conditions, the polarization current frequently fell below the desired value during dry spells even though the slabs had sponges attached to their upper surfaces.

c) Analytical Procedure for Determination of Chloride Concentration Profiles

The slabs were sampled by drilling a hole above a rebar and removing the resultant powdered drillings at certain depths. The sampling procedure involved two drill bits, a small sampling bit (1/2 inch diameter) and a larger bit (3/4 inch diameter) to increase the diameter of the hole between samples. The sample at a given depth was drilled from the base of the hole and collected by suction into a weighed flask; the depth of the drilling could be controlled to sample at depth increments as small as 0.2 cm. Between samples, the sampling hole was drilled to a larger diameter and the loose material discarded. The double drilling was to ensure that the sample from a given depth was not contaminated with material from the side of the sample hole.

The normal procedure was to take two 2 mm samples, then three 10 mm samples, one 5 mm sample and 2 mm sections until the rebar was reached. The depth to the rebar was in the range of 43 to 49 mm. For the concrete slabs, eight holes were drilled and the individual depth samples composited in order to obtain a representative sample. The resultant samples were then dried overnight in a vacuum oven at 60°C. They were then reweighed and analysed for total chloride as follows.

About 10 mL of water was added to each flask containing up to 3g of sample followed by 3 mL of concentrated nitric acid. After the reaction ceased, approximately 50 mL of water was added and the contents heated to 80°C for 15 minutes. They were then filtered through number 41 and 40 filter papers and the residue washed with hot water. The filtrates were then titrated against 0.02 M $AgNO_3$ solution using a chloride specific ion electrode. In cases where low levels of chloride were present, 2 mL of 0.01 M NaCl solution was added in order to obtain a satisfactory end point.

E. Discussion

a) Variation of chloride profiles with time.

Initial chloride concentrations for the five batches of mortar and concrete were determined both for the test cylinders and the slabs. Results for the cylinders are given in Table 3.

Table 4 lists the mean chloride levels in the slabs at time=0 before connection to the cathodic protection system. As can be seen by comparing the two tables, there is good agreement between the two sets of data.

The initial profiles were, as expected, not uniform but showed a gradual decrease near the rebar as shown in Figure 2 for CM3, t=0. The slabs were sampled at various time intervals after connection and the complete analytical results are given in Appendix 1. For slabs CM3, Table 5 and Figure 3 give the mean chloride concentrations between the anode and cathode and the mean concentration in the 10 mm adjacent to the rebar as a function of time; Figure 2 shows the profiles graphically for time 0, 245 and 776 days. As can be seen, there is a gradual decrease in chloride present in the slabs with a general migration away from the cathode. The chloride concentration profiles all show a low level of chloride in the initial 2 mm layer. This initial depletion was first thought to be a result of skimming off the surface layer during preparation of the slabs but we have no rational explanation for its persistence over the course of the study.

For the concrete slabs at the same current density of 50 mA m^{-2}, the results are similar. Table 6 and Figure 4 show the variation of chloride concentration with time. The percentage decrease in chloride levels is similar for the two cases.

For the mortar and concrete slabs at 10 mA m^{-2}, DM5 and BC2, no overall decrease in chloride concentration was seen. Table 7 lists the data for slabs DM5; the concrete slabs BC2 have not been reanalyzed because of the time involved but the results might be expected to be similar to those for DM5. Similarly, for the outdoor slabs no significant movement of chloride was discernable.

The single slab, MS-17, which was subjected to the highest current density (222 mA m^{-2}), exhibited accelerated movement of chloride ions away from the cathode. Figure 5 shows the decrease of chloride in the slab and, in particular, near the rebar with time. The anode on this slab deteriorated quite rapidly and had to be repaired on a number of occasions; the sponge also showed decomposition presumably due to attack from chlorine being evolved at the anode.

The measured amount of chloride removed from the slabs can be compared to the amount that would have been removed if the sole anode reaction had been the oxidation of chloride to chlorine gas in order to give an estimation of the percentage of current carried by chloride ions in the slabs. Table 8 lists the current efficiencies for removal of chloride obtained based on the amount of electricity used over various periods of cathodic protection and the amount of chloride removed. The calculations are based on a slab area of 0.09 m^2, a depth from surface to rebar of 4.4 cm, and a slab density of 2.2 g/cm^3. The calculation overestimates the amount of chloride lost from the system during electrolysis. The sampling for the concentration profiles was done directly over the rebar, and the assumption that the concentration profiles were uniform over the whole slab cross section is incorrect. The depletion of chloride is concentrated over the rebar, and the actual depletion of chloride from the slab is significantly less than that calculated. A sample calculation is given in Appendix 2.

For slab MS-17, a core was taken between two rebars and the chloride concentration profile compared with that directly over the rebar. The mean chloride concentration from the anode to the rebar depth was 0.299% compared with 0.239% for a core directly above the rebar (at time = 0 the concentration was 0.367%) and this represents a decrease of 54.5%. The difference in chloride concentration profiles for these two cores as compared with the initial profile is shown in Figure 6. The corrected current efficiencies in Table 8 reflected the 54.5% decrease in chloride depletion observed in MS-17.

If a current efficiency of 8% is assumed, then for slabs DM5 under cathodic protection with current densities of 10 mA m^{-2}, there would be expected to be an overall decrease of 0.012% chloride after 463 days; for a current efficiency of 4% the decrease would be 0.006%. Examination of the data for DM5 shows that a decrease of this order of magnitude is not statistically significant.

In late March 1986 several slabs were broken in order to examine the imbedded rebars for corrosion. One slab that had been in the constant humidity enclosure since the start of the project but had not been under cathodic protection was used as a control. The photographs (Figures 7 and 8) show the four slabs that were examined: Control (Mortar), DM5 (Mortar, 10 mA m^{-2}), BC2 (Concrete, 10 mA m^{-2}); and AC1 (Concrete, 50 mA m^{-2}).

The control slab showed considerable rusting of the rebar at the end where the bar had been primed and was embedded in the mortar. This is not found in any of the other three slabs. The rebar in AC1 which had been under cathodic protection at the high current density of 50 mA m^{-2} showed considerable blackening on the surface. The black material at the interface of the rebar and concrete or mortar was found on two other slabs at

the 50 mA m^{-2} current density level and also MS-17 at 222 mA m^{-2}. It was only present on the upper half of the rebar facing the anode. X-ray diffraction analysis of the black material is inconclusive but the most likely candidates are Fe_3O_4 or $MgFe_2O_4$.

b) Effect of removal or reduction of cathodic protection

The effect of removal of cathodic protection from the CM3 slabs was studied in two separate experiments.

On 12 June 1985, two slabs MS-3 and MS-7 were disconnected from the 50 mA m^{-2} current but left in the constant humidity chamber. Chloride concentration profiles were determined in January 1986. These showed an increase in chloride levels near to the rebar (see Figure 9) but the changes were not considered conclusive and the experiment was repeated.

On 5 February 1986, slab MS-2 was disconnected; two holes A and B were drilled prior to this in order to establish two chloride concentration profiles in the slab. Three holes, two adjacent to hole A and one near to hole B were drilled and profiles obtained in October and November 1986. These again showed migration of chloride ion back towards the rebar as illustrated in Figures 10 and 11.

During this same time period another slab from the CM3 group, MS-5 was connected to a cathodic protection circuit under a reduced current density of 1 mA m^{-2}. Again, two holes A and B were drilled and profiles obtained in early February 1986. Resampling of the slab in November 1986 at adjacent sites gave chloride concentration profiles which showed similar chloride migration back towards the rebars as was exhibited by the disconnected slab (Figure 12 and 13).

Table 1

Mortar (MS) and Concrete (CS) Slabs:

Batch 1	Concrete	Prepared 07/05/84
	CS-1, 2, 3, 4, 5, 6, 7, 8, 9	
Batch 2	Concrete	Prepared 09/05/84
	CS-10, 11, 12, 13, 14, 15, 16, 17, 18	
Batch 3	Mortar	Prepared 10/05/84
	MS-1, 2, 3, 4, 5, 6, 7, 8	
Batch 4	Mortar	Prepared 14/05/84
	MS-9, 10, 11, 12, 13, 14, 15, 16	
Batch 5	Mortar	Prepared 15/05/84
	MS-17, 18, 19, 20, 21, 22, 23, 24	

All slabs cured for 28 days before sides coated with Glidden Glid Guard Epoxy Chemical Resistant Finish 5250 Tinting Brown Gloss plus 5242 Curing Agent.

Slab Sets for Migration Studies

Set	Material/Batch	Slabs	Experiment
AC1	Concrete/1	CS-1,2,3,4,5,6	Controlled Humidity
BC2	Concrete/2	CS-13,14,15,16,17,18	Controlled Humidity
CM3	Mortar/3	MS-2,3,5,6,7,8	Controlled Humidity
DM5	Mortar/5	MS-19,20,21,22,23,24	Controlled Humidity
EC1	Concrete/1	CS-7,8,9	Outdoor Exposure
EC2	Concrete/2	CS-10,11,12	Outdoor Exposure
FM4	Mortar/4	MS-10,11,12,14,15,16	Outdoor Exposure

Table 2

Mortar and Concrete Cylinders for Reference Analyses

Batch	Material	Cylinders
1	Concrete	C1-NC-1, C1-NC-2
1	Concrete/Chloride Added	C1-CC-1, C1-CC-2
2	Concrete	C2-NC-1, C2-NC-2
2	Concrete/Chloride Added	C2-CC-1, C2-CC-2
3	Mortar	M3-NC-1, M3-NC-2
3	Mortar/Chloride Added	M3-CC-1, M3-CC-2
4	Mortar	M4-NC-1, M4-NC-2
4	Mortar/Chloride Added	M4-CC-1, M4-CC-2
5	Mortar	M5-NC-1, M5-NC-2
5	Mortar/Chloride Added	M5-CC-1, M5-CC-2

Chloride added material prepared with 0.5% by weight added $CaCl_2$ $2H_2O$.

Table 3

Chloride Analyses on Test Cylinders

Cylinder	% Chloride	Mean % Chloride
C1-NC-1	0.014, 0.014	0.014
C1-CC-1	0.263, 0.269	0.266
C2-CC-1	0.277, 0.278, 0.275	0.277
M3-NC-1	0.058, 0.053, 0.058	0.056
M3-CC-1	0.379, 0.375, 0.382	0.379
M4-NC-1	0.017, 0.017	0.017
M4-CC-1	0.342, 0.342	0.342
M5-CC-1	0.367, 0.368, 0.369	0.368

Table 4

Chloride levels in the slabs at time zero

Slab	% Chloride	Mean % Chloride
AC1	0.270	0.270
BC2	0.262, 0.258, 0.250	0.256
EC1	0.265	0.265
EC2	-	-
CM3	0.375, 0.380, 0.363	0.372
FM4	0.334, 0.343, 0.331, 0.351	0.340
DM5	0.358, 0.397, 0.376	0.377

Table 5

Variation in Chloride Concentration with Time for CM3 Slabs

Time (days)	0	31	66	98	154	245	469	472	776
Mean % Cl above rebar	0.372	0.380	0.374	0.352	0.344	0.326	0.303	0.282	0.271
Mean % Cl-10 mm adjacent to rebar	0.329	0.350	0.344	0.294	0.257	0.268	0.231	0.180	0.229

Table 6

Variation in Chloride Concentration With Time for AC1 Slabs

Time (days)	0	183	497
Mean % Cl above rebar	0.270	0.229	0.192
Mean % Cl - 10 mm adjacent to rebar	0.243	0.194	0.143

Table 7

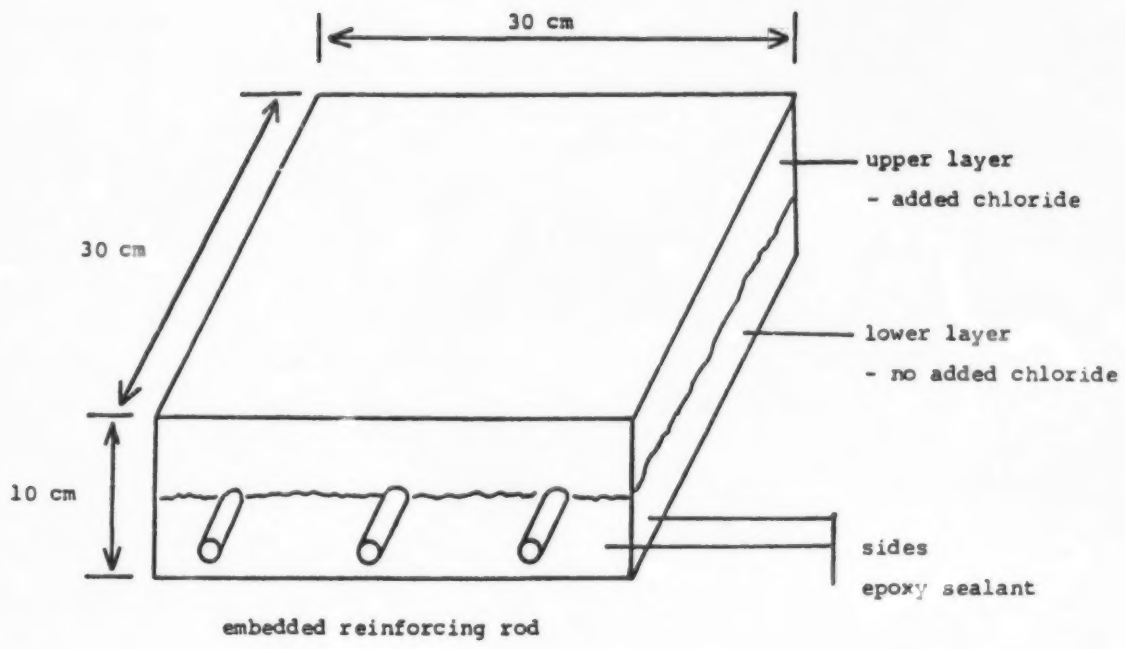
Variation in Chloride Concentration With Time for DM5 Slabs

Time (days)	0	155	463
Mean % Cl above rebar	0.377	0.345	0.354
Mean % Cl - 10 mm adjacent to rebar	0.351	0.311	0.352

Table 8

Calculated Percent of Current Used in Chloride Oxidation at the Anode

Slab	Current Density	Time	Uncorrected Current Efficiency (%)	Corrected Current Efficiency (%)
MS17	222 mA m^{-2}	74 days	19.7	10.7
MS17	222 mA m^{-2}	118 days	14.4	7.8
MS17	222 mA m^{-2}	354 days	7.0	3.6
CM3	50 mA m^{-2}	154 days	7.5	4.1
CM3	50 mA m^{-2}	245 days	9.2	5.0
CM3	50 mA m^{-2}	477 days	7.8	4.3
CM3	50 mA m^{-2}	776 days	7.2	3.9



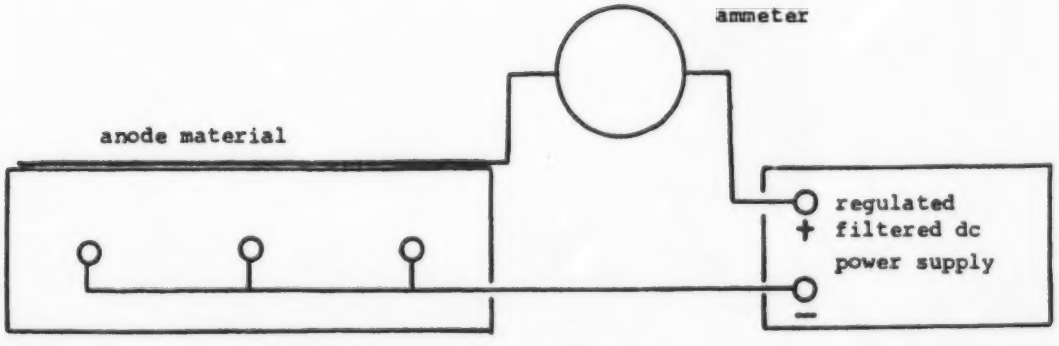


Figure 1a/ Concrete/Mortar Slabs and Cathodic Protection Circuit

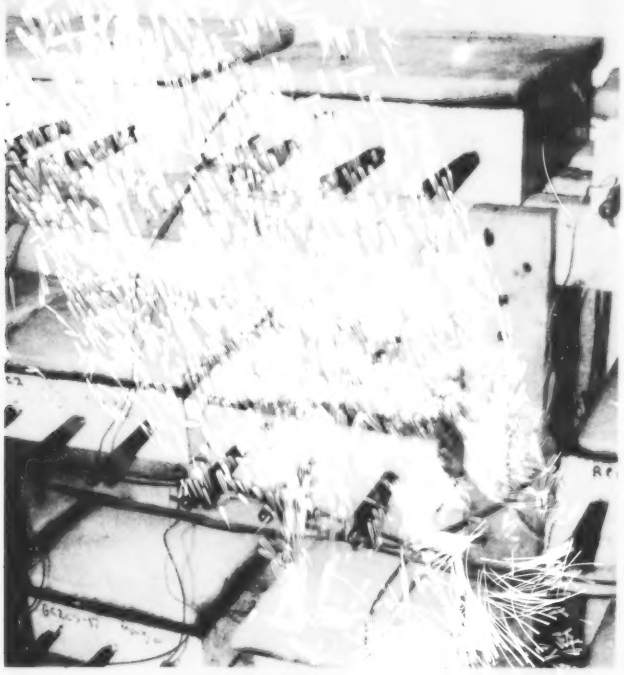


Figure 1b(i)/ Mortar and Concrete Slabs in the Constant Humidity Enclosure

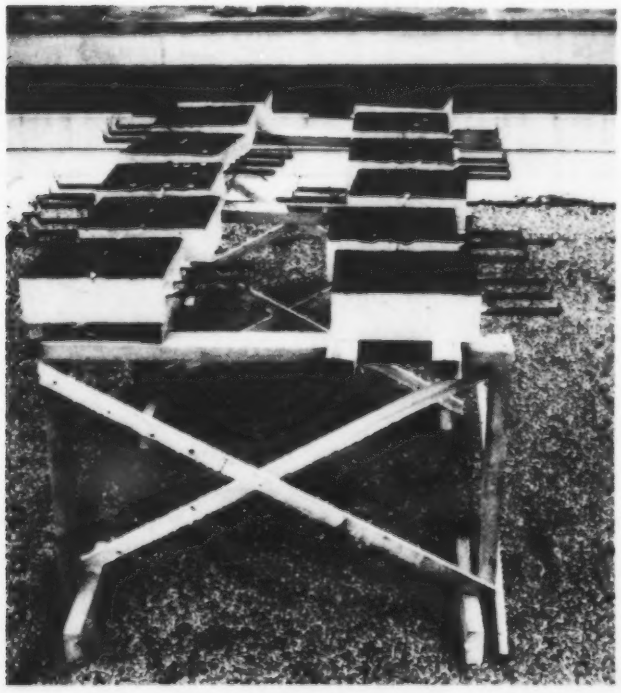


Figure 1b(ii)/ Mortar and Concrete Slabs on the Roof of the Chemistry Department

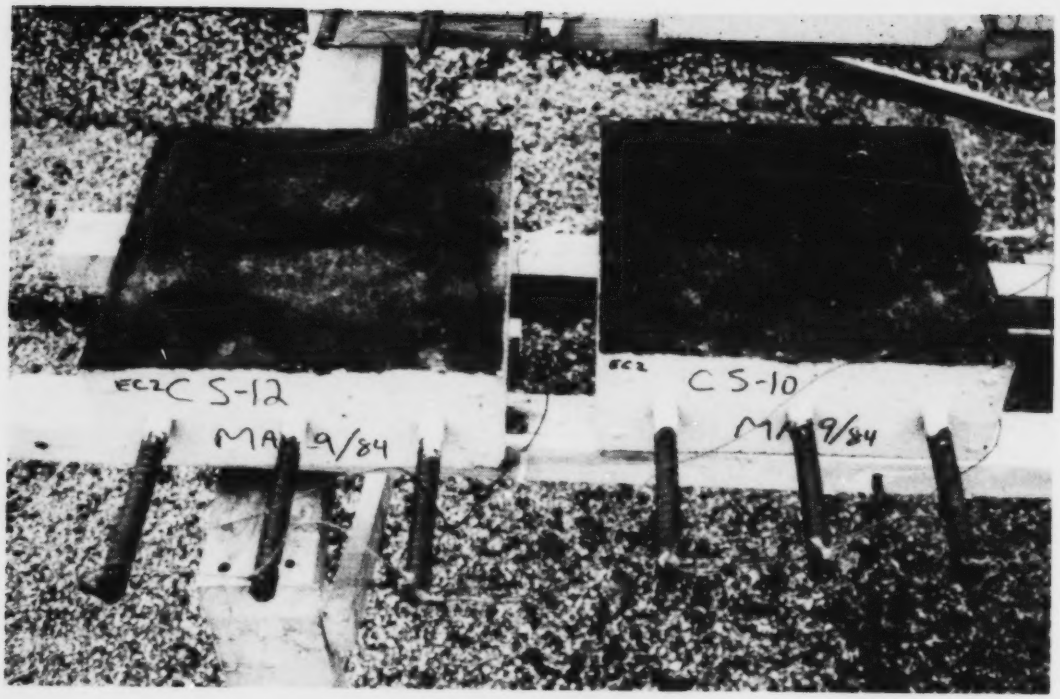


Figure 1c(i)/ Two Concrete Slabs on the Roof of the Chemistry Department

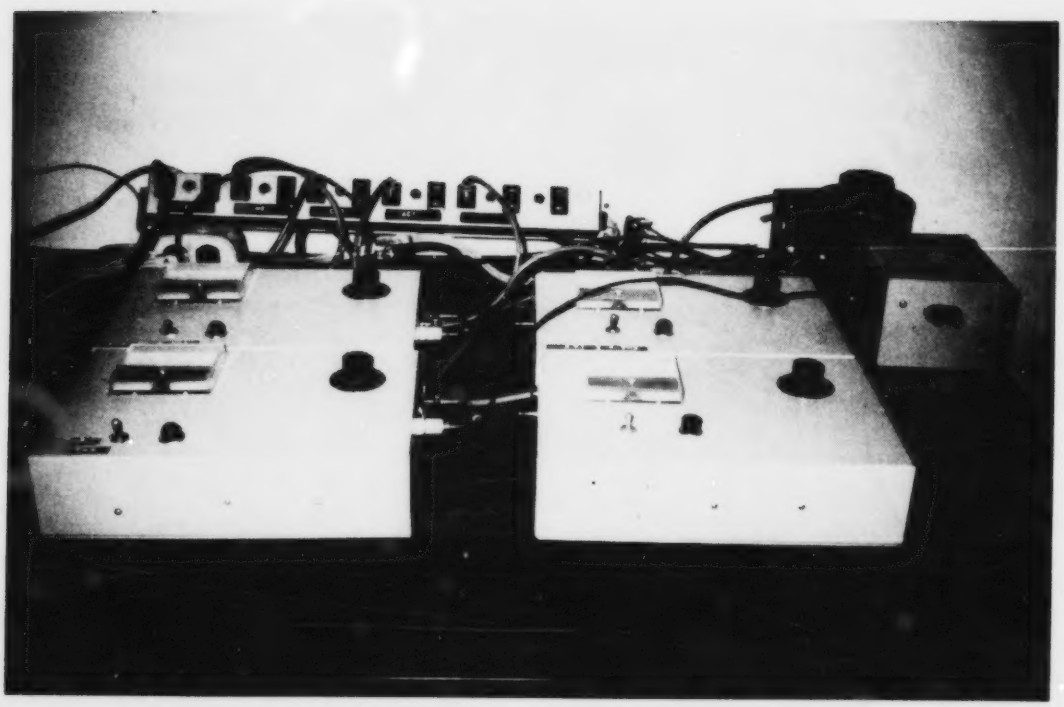


Figure 1c(ii)/ Power Supplies for the Slabs in the Constant Humidity Enclosure

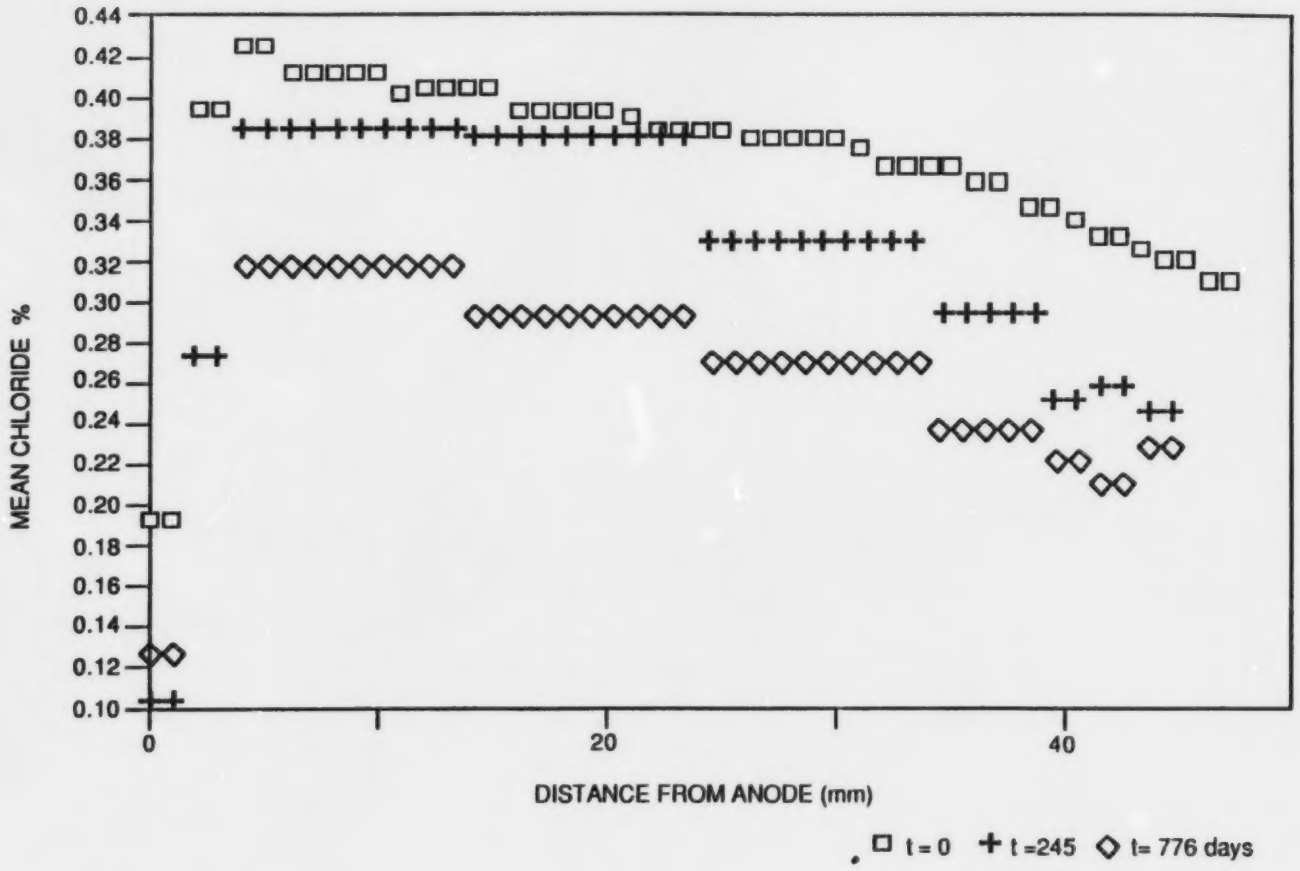


Figure 2/ Chloride Levels as a Function of Time, Mortar Slabs CM3 (50 mA)

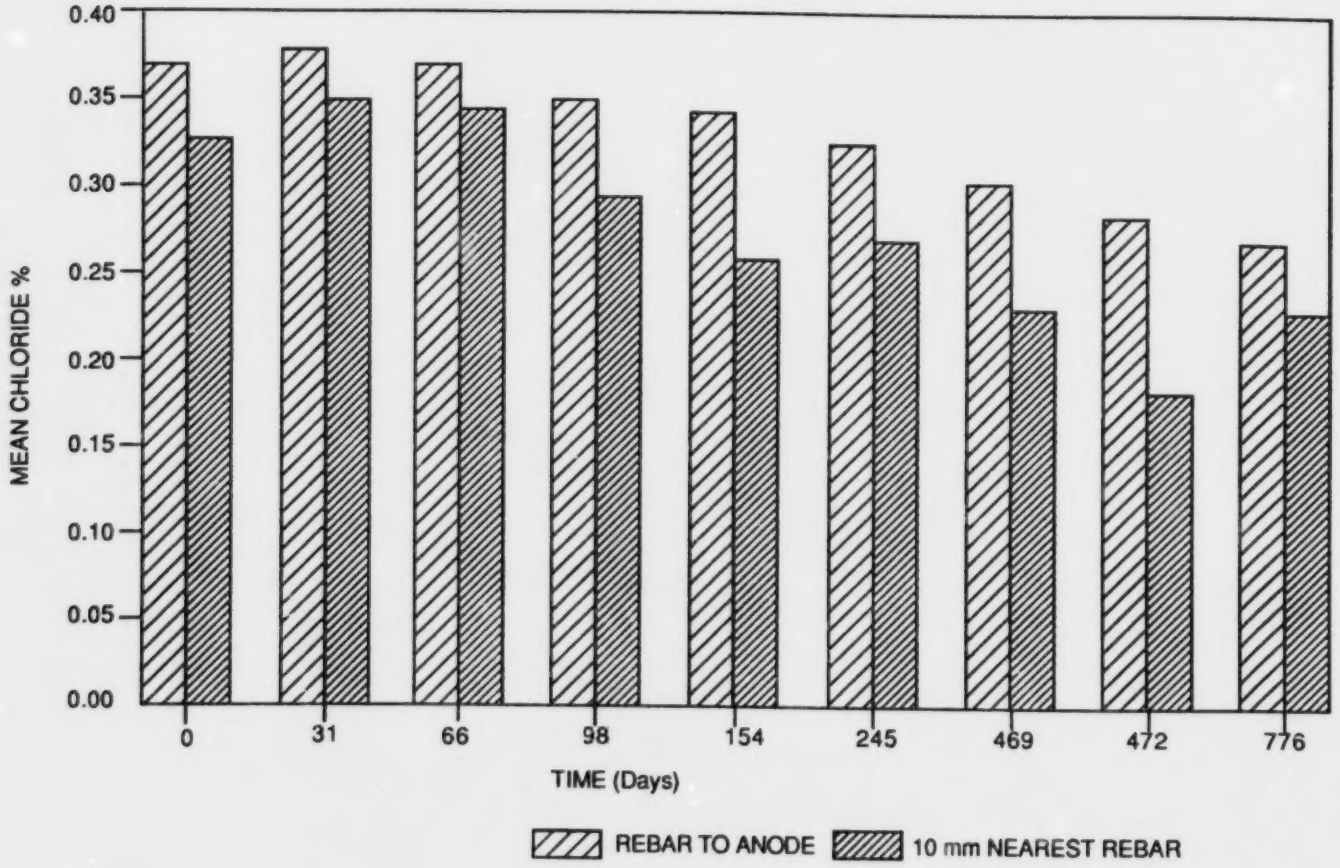


Figure 3/ Chloride Levels as a Function of Time, Mortar Slabs CM3 (50 mA)

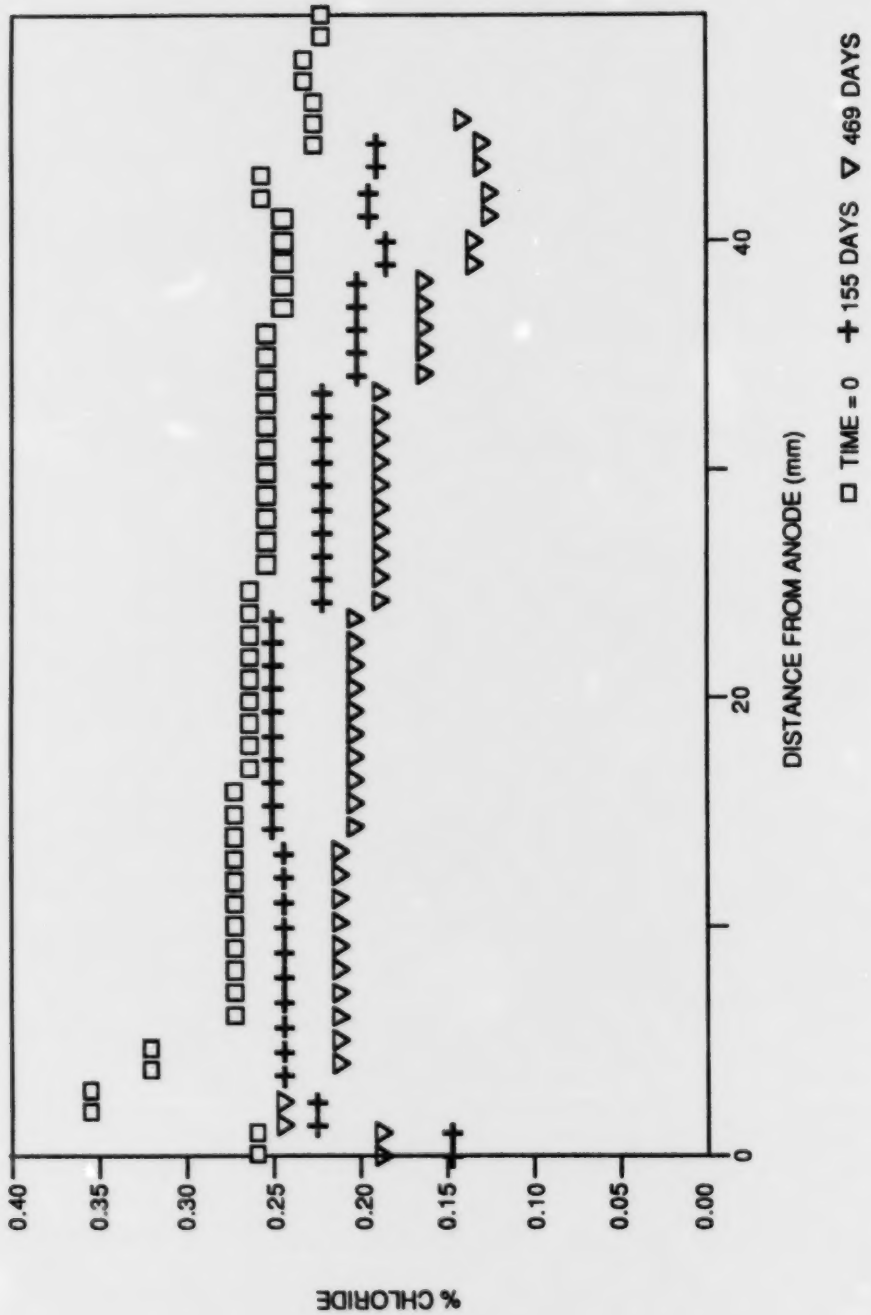


Figure 4/ Chloride Levels as a Function of Time, Concrete Slabs AC1 (50 mA)

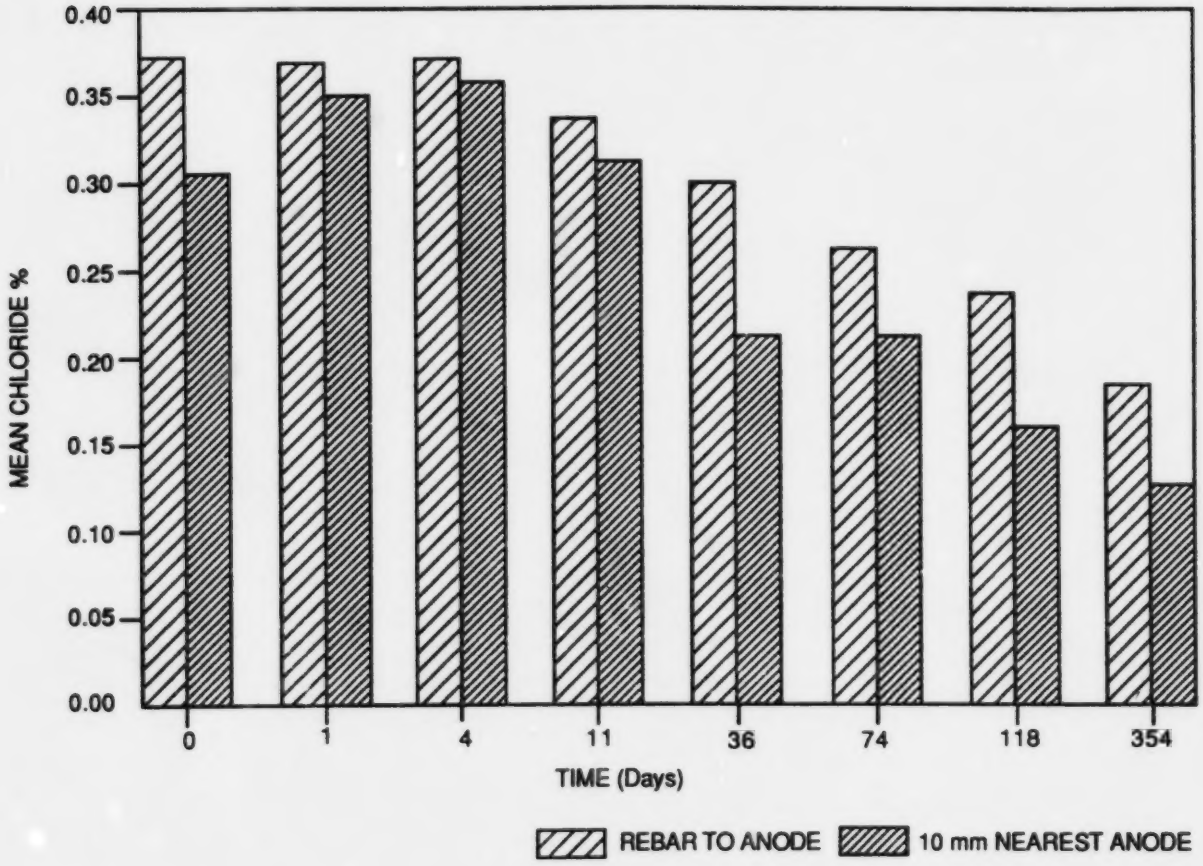


Figure 5/ Chloride Levels as a Function of Time, Mortar Slab MS-17 (222 mA)

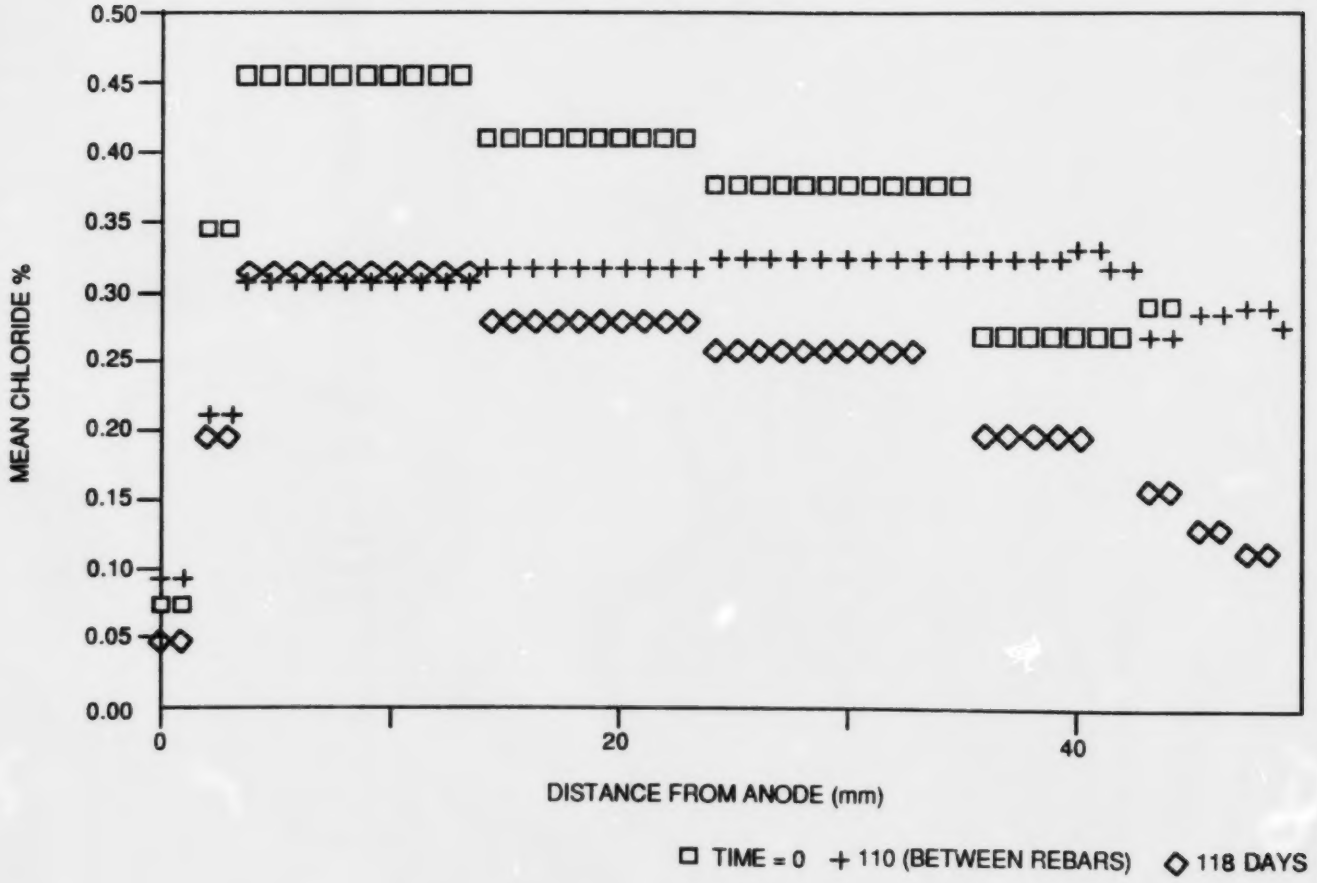


Figure 6/ Chloride Levels as a Function of Time, Mortar Slab MS-17 (222 mA)

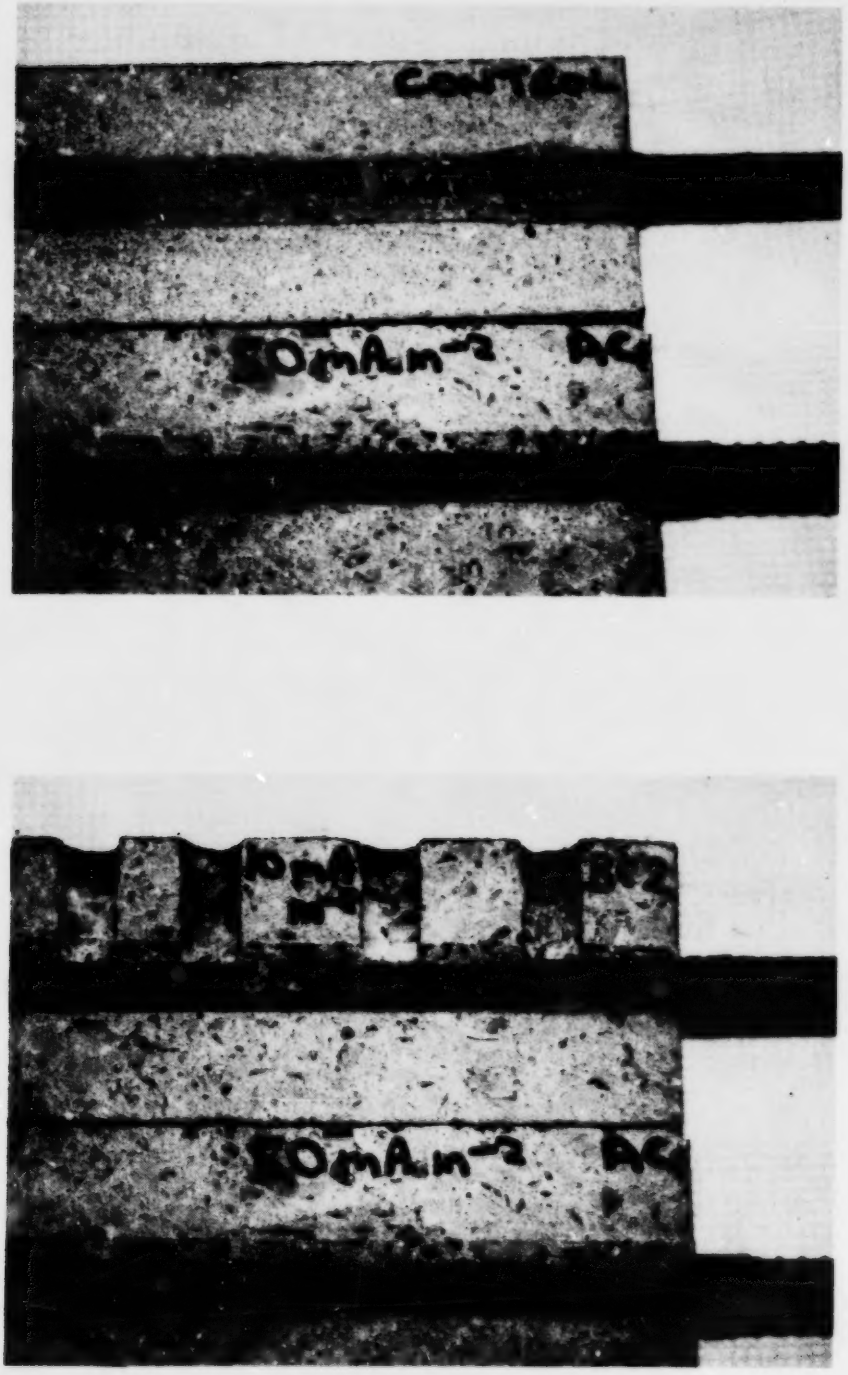


Figure 7/ Slabs and Rebars Showing the Effect of Cathodic Protection

Figure 8/ Slabs and Rebars Showing the Effect of Cathodic Protection

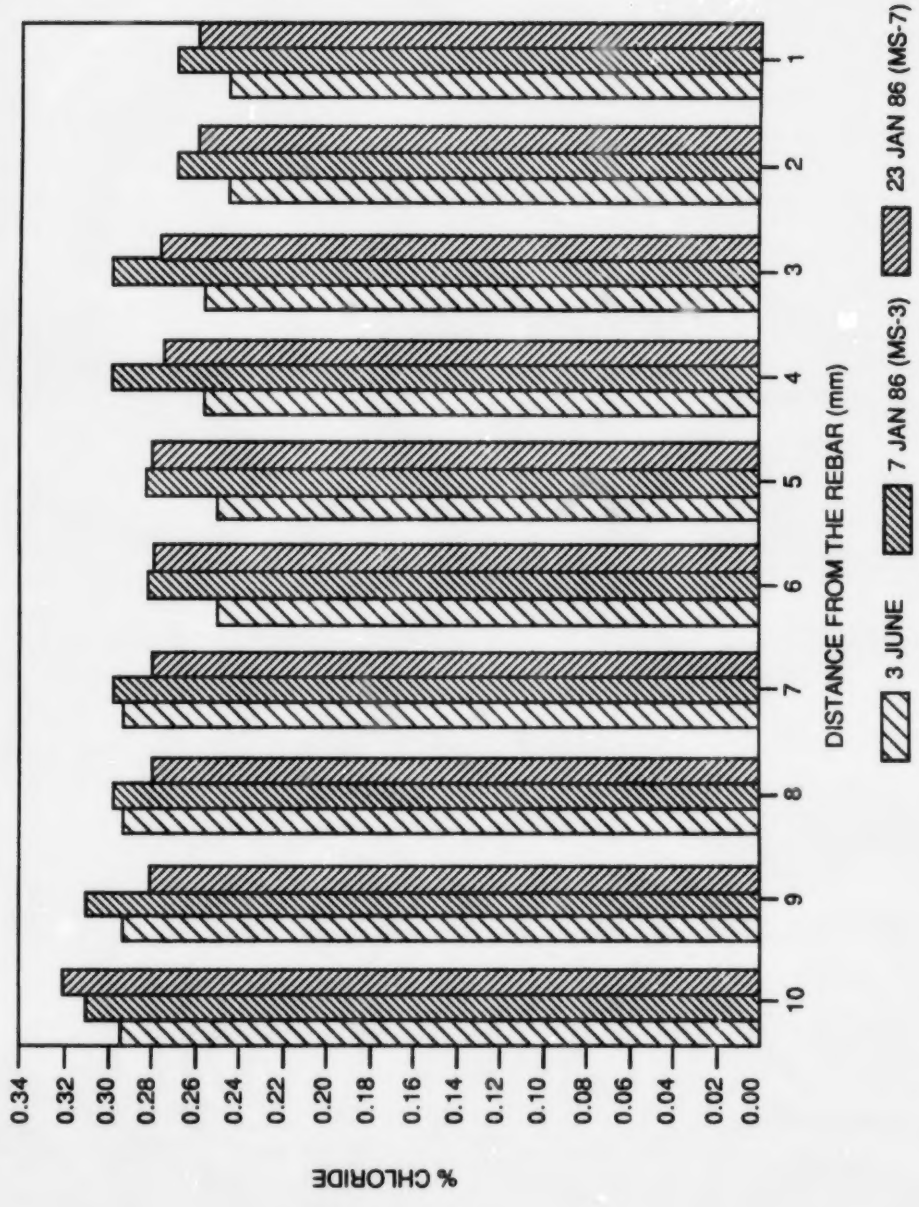


Figure 9/ Chloride Levels as a Function of Time, Slabs MS-3 and MS-7, Removed 12.06.85

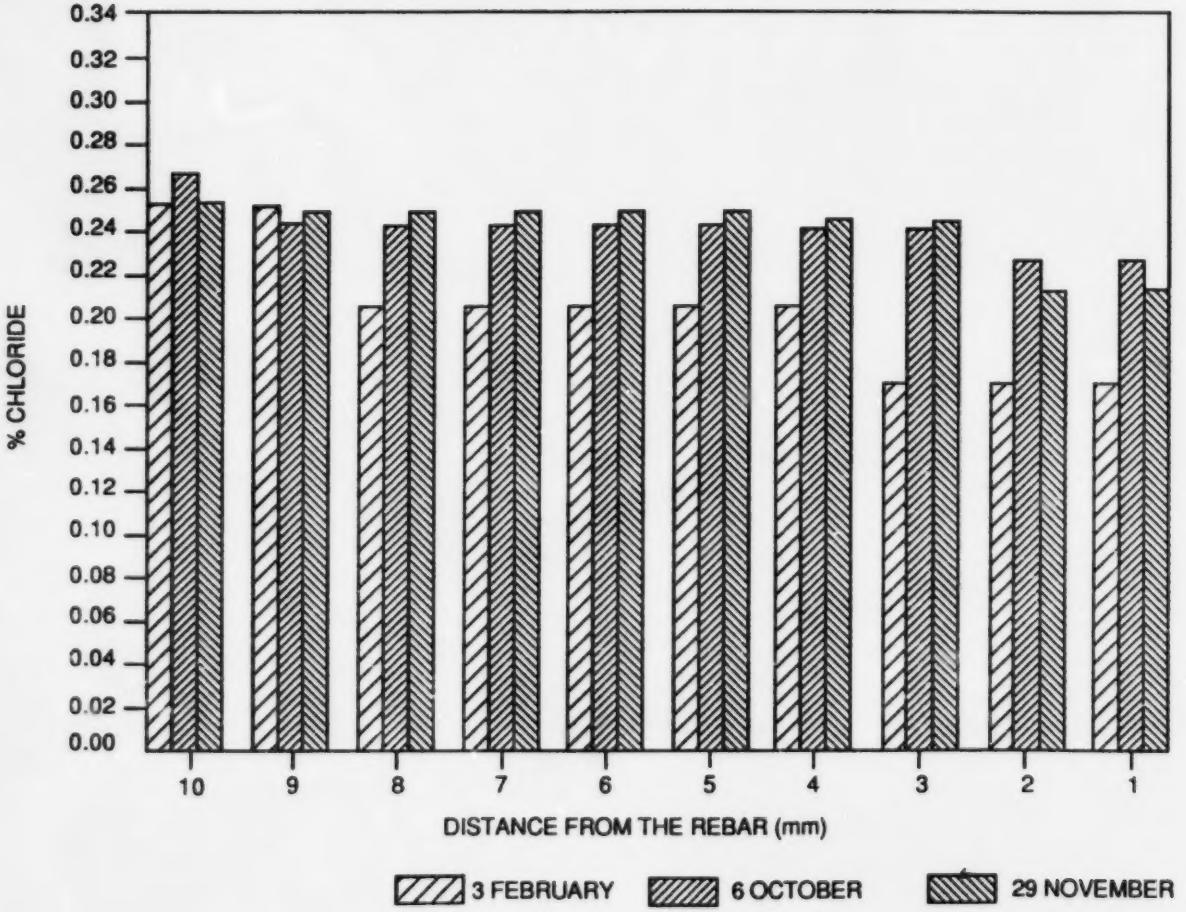


Figure 10/ Chloride Levels as a Function of Time, Slab MS-2, Removed 05.02.86 (Hole A)

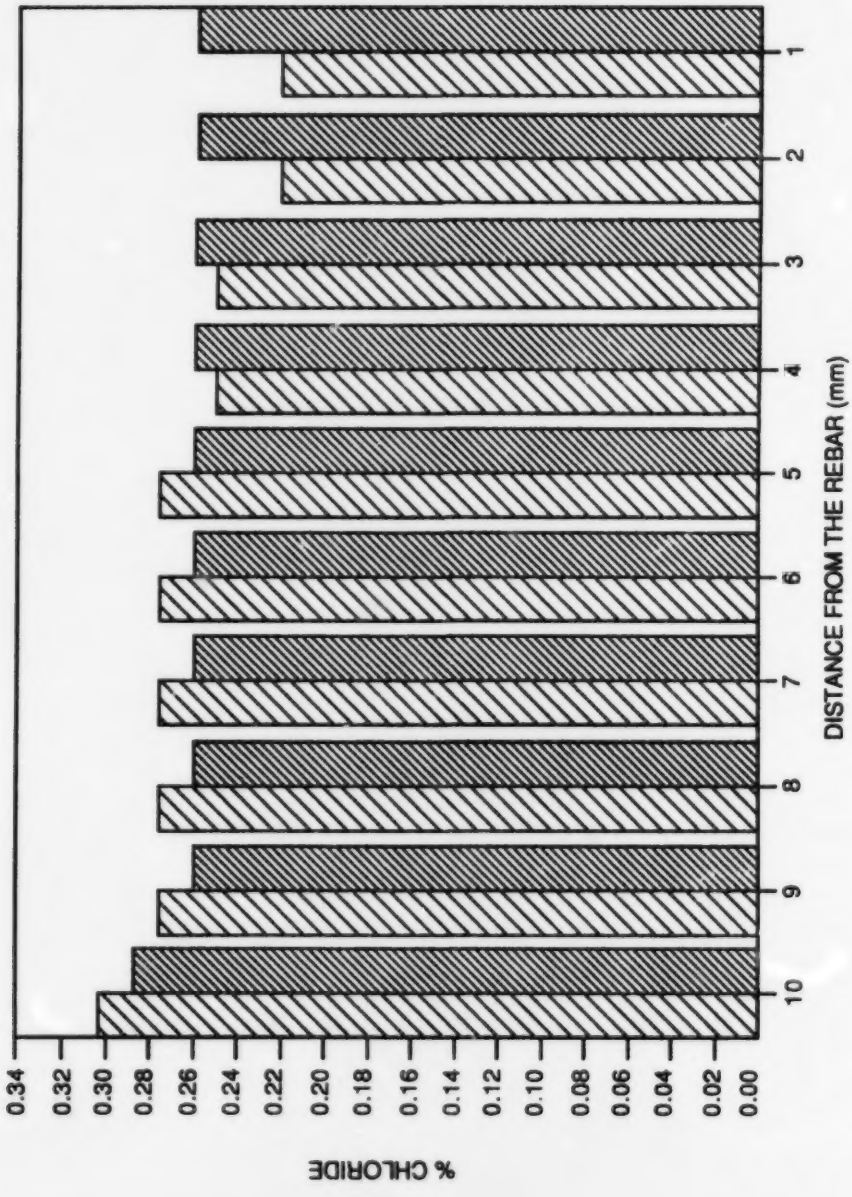


Figure 11/ Chloride Levels as a Function of Time, Slab MS-2, Removed 05.02.86 (Hole B)

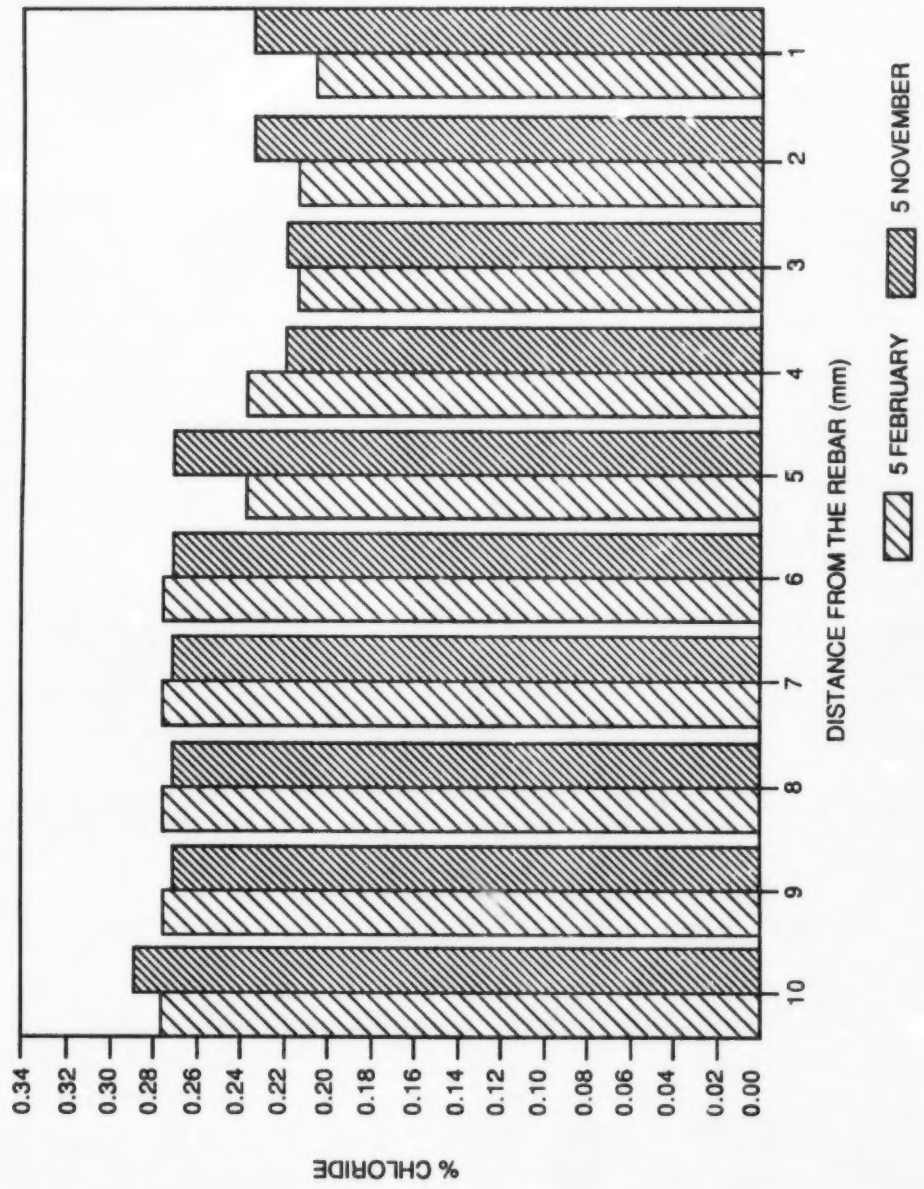


Figure 12/ Chloride Levels as a Function of Time, Slab MS-5 (1 mA), from 14.02.86 (Hole A)

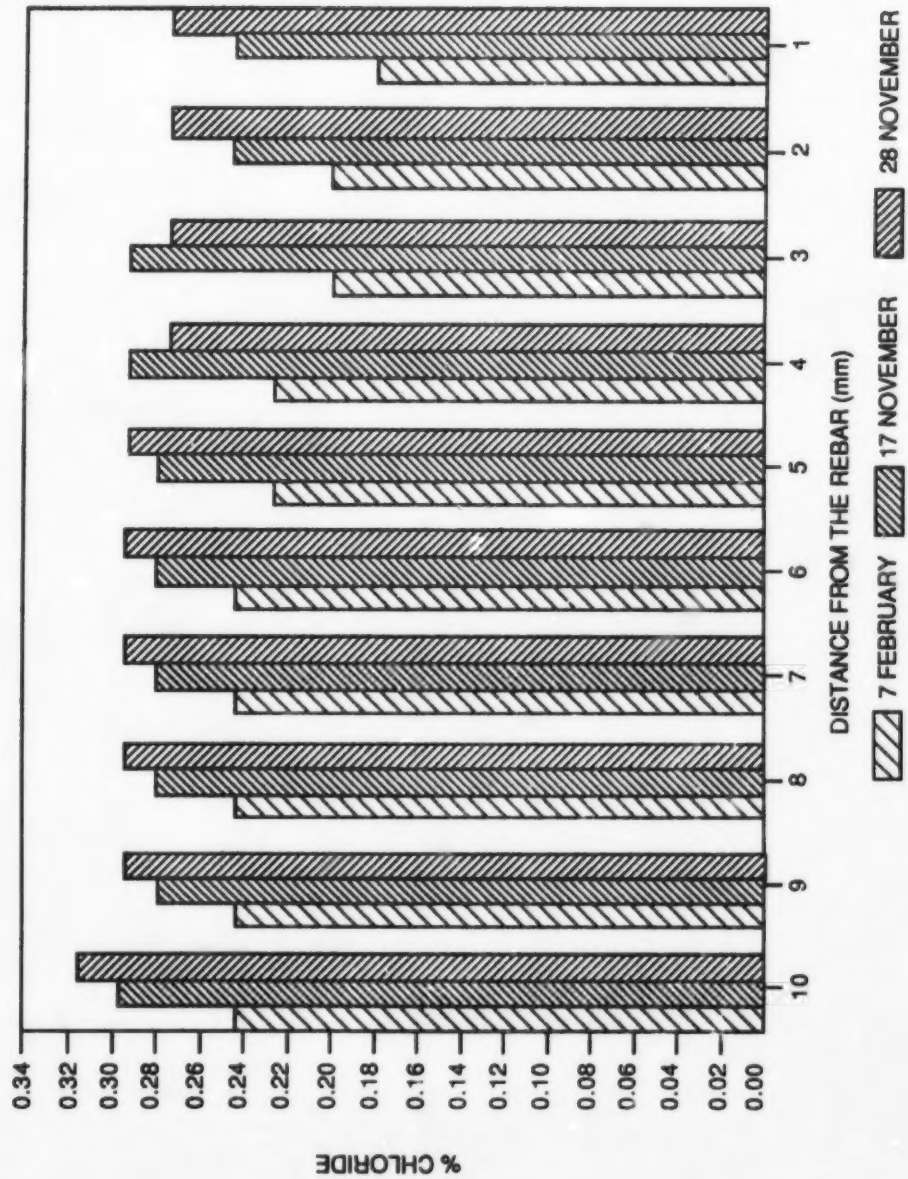


Figure 13/ Chloride Levels as a Function of Time, Slab MS-5 (1 mA), from 14.02.86 (Hole B)

APPENDIX 1

CHLORIDE CONCENTRATION PROFILES

The experimentally obtained values of the chloride concentration are tabulated as a function of depth and time for each set of slabs. Each column represents a hole drilled in a slab.

CATHODIC PROTECTION DATA
MORTAR BLOCKS 50mA PER SQUARE METER (CM3)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0	0	0	0	31	66
DEPTH	17.08.84	11.09.84	13.09.84	AVERAGE	01.11.84	06.12.84
0	0.107	0.307	0.164	0.193	0.179	0.117
1	0.107	0.307	0.164	0.193	0.179	0.117
2	0.357	0.446	0.380	0.394	0.376	0.364
3	0.357	0.446	0.380	0.394	0.376	0.364
4	0.436	0.451	0.390	0.426	0.460	0.454
5	0.436	0.451	0.390	0.426	0.460	0.454
6	0.432	0.421	0.382	0.412	0.393	0.427
7	0.432	0.421	0.382	0.412	0.393	0.427
8	0.432	0.421	0.382	0.412	0.393	0.427
9	0.432	0.421	0.382	0.412	0.393	0.427
10	0.432	0.421	0.382	0.412	0.393	0.427
11	0.403	0.421	0.382	0.402	0.393	0.427
12	0.403	0.421	0.392	0.405	0.413	0.405
13	0.403	0.421	0.392	0.405	0.413	0.405
14	0.403	0.421	0.392	0.405	0.413	0.405
15	0.403	0.421	0.392	0.405	0.413	0.405
16	0.396	0.394	0.392	0.394	0.413	0.405
17	0.396	0.394	0.392	0.394	0.413	0.405
18	0.396	0.394	0.392	0.394	0.413	0.405
19	0.396	0.394	0.392	0.394	0.413	0.405
20	0.396	0.394	0.392	0.394	0.413	0.405
21	0.396	0.383	0.392	0.390	0.413	0.405
22	0.396	0.383	0.373	0.384	0.400	0.379
23	0.396	0.383	0.373	0.384	0.400	0.379
24	0.396	0.383	0.373	0.384	0.400	0.379
25	0.396	0.383	0.373	0.384	0.400	0.379
26	0.386	0.383	0.373	0.381	0.400	0.379
27	0.386	0.383	0.373	0.381	0.400	0.379
28	0.386	0.383	0.373	0.381	0.400	0.379
29	0.386	0.383	0.373	0.381	0.400	0.379
30	0.386	0.383	0.373	0.381	0.400	0.379
31	0.375	0.383	0.373	0.377	0.400	0.379
32	0.375	0.366	0.361	0.367	0.362	0.370
33	0.375	0.366	0.361	0.367	0.362	0.370
34	0.375	0.366	0.361	0.367	0.362	0.370
35	0.375	0.366	0.361	0.367	0.362	0.370
36	0.361	0.366	0.361	0.363	0.362	0.370
37	0.361	0.366	0.361	0.363	0.362	0.370
38	0.361	0.350	0.334	0.348	0.353	0.365
39	0.361	0.350	0.334	0.348	0.353	0.365
40	0.361	0.329	0.334	0.341	0.375	0.377
41	0.335	0.329	0.335	0.333	0.375	0.377
42	0.335	0.329	0.335	0.333	0.348	0.358
43	0.341	0.329	0.302	0.324	0.348	0.358
44	0.341	0.299		0.320	0.311	0.343
45	0.341	0.299		0.320	0.311	0.343
46		0.311		0.311		0.275
47		0.311		0.311		0.275
48						
MEAN	0.375	0.380	0.363	0.372	0.380	0.374

CATHODIC PROTECTION DATA
MORTAR BLOCKS 50mA PER SQUARE METER (CM3)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0	98	154	245	469	472	776
DEPTH	AVERAGE	07.01.85	04.03.85	03.06.85	15.01.86	28.01.86	24.11.86
0	0.193	0.108	0.219	0.103	0.214	0.330	0.126
1	0.193	0.108	0.219	0.103	0.214	0.330	0.126
2	0.394	0.317	0.362	0.274	0.372	0.350	0.303
3	0.394	0.317	0.362	0.274	0.372	0.350	0.303
4	0.426	0.398	0.392	0.386	0.361	0.305	0.317
5	0.426	0.398	0.392	0.386	0.361	0.305	0.317
6	0.412	0.398	0.392	0.386	0.361	0.305	0.317
7	0.412	0.398	0.392	0.386	0.361	0.305	0.317
8	0.412	0.398	0.392	0.386	0.361	0.305	0.317
9	0.412	0.398	0.392	0.386	0.361	0.305	0.317
10	0.412	0.398	0.392	0.386	0.361	0.305	0.317
11	0.402	0.398	0.392	0.386	0.361	0.305	0.317
12	0.405	0.398	0.392	0.386	0.361	0.305	0.317
13	0.405	0.398	0.392	0.386	0.361	0.305	0.317
14	0.405	0.398	0.386	0.380	0.340	0.360	0.295
15	0.405	0.398	0.386	0.380	0.340	0.360	0.295
16	0.394	0.398	0.386	0.380	0.340	0.360	0.295
17	0.394	0.398	0.386	0.380	0.340	0.360	0.295
18	0.394	0.398	0.386	0.380	0.340	0.360	0.295
19	0.394	0.398	0.386	0.380	0.340	0.360	0.295
20	0.394	0.398	0.386	0.380	0.340	0.360	0.295
21	0.390	0.398	0.386	0.380	0.340	0.360	0.295
22	0.384	0.398	0.386	0.380	0.340	0.360	0.295
23	0.384	0.398	0.386	0.380	0.340	0.360	0.295
24	0.384	0.375	0.368	0.329	0.296	0.269	0.271
25	0.384	0.375	0.368	0.329	0.296	0.269	0.271
26	0.381	0.375	0.368	0.329	0.296	0.269	0.271
27	0.381	0.375	0.368	0.329	0.296	0.269	0.271
28	0.381	0.375	0.368	0.329	0.296	0.269	0.271
29	0.381	0.375	0.368	0.329	0.296	0.269	0.271
30	0.381	0.375	0.368	0.329	0.296	0.269	0.271
31	0.377	0.375	0.368	0.329	0.296	0.269	0.271
32	0.367	0.375	0.368	0.329	0.296	0.269	0.271
33	0.367	0.375	0.368	0.329	0.296	0.269	0.271
34	0.367	0.342	0.331	0.294	0.264	0.227	0.238
35	0.367	0.342	0.331	0.294	0.264	0.227	0.238
36	0.363	0.342	0.331	0.294	0.264	0.227	0.238
37	0.363	0.342	0.331	0.294	0.264	0.227	0.238
38	0.348	0.342	0.331	0.294	0.264	0.227	0.238
39	0.348	0.315	0.296	0.250	0.249	0.199	0.226
40	0.341	0.315	0.296	0.250	0.249	0.199	0.226
41	0.333	0.295	0.276	0.258	0.225	0.172	0.210
42	0.333	0.295	0.276	0.258	0.225	0.172	0.210
43	0.324	0.262	0.246	0.246	0.226	0.144	0.233
44	0.320	0.262	0.246	0.246	0.226	0.144	0.233
45	0.320	0.255	0.243		0.191	0.085	
46	0.311	0.255	0.243		0.191		
47	0.311		0.225				
48			0.225				
MEAN	0.372	0.352	0.344	0.326	0.303	0.282	0.271

CATHODIC PROTECTION DATA
MORTAR BLOCKS 50mA PER SQUARE METER (CM3)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

BLOCKS REMOVED 12.06.85

SLAB		MS-3	MS-7
TIME	245		
DEPTH	03.06.85	07.01.86	23.01.86
0	0.103	0.093	0.113
1	0.103	0.093	0.113
2	0.274	0.383	0.311
3	0.274	0.383	0.311
4	0.386	0.377	0.355
5	0.386	0.377	0.355
6	0.386	0.377	0.355
7	0.386	0.377	0.355
8	0.386	0.377	0.355
9	0.386	0.377	0.355
10	0.386	0.377	0.355
11	0.386	0.377	0.355
12	0.386	0.377	0.355
13	0.386	0.377	0.355
14	0.380	0.362	0.337
15	0.380	0.362	0.337
16	0.380	0.362	0.337
17	0.380	0.362	0.337
18	0.380	0.362	0.337
19	0.380	0.362	0.337
20	0.380	0.362	0.337
21	0.380	0.362	0.337
22	0.380	0.362	0.337
23	0.380	0.362	0.337
24	0.329	0.343	0.321
25	0.329	0.343	0.321
26	0.329	0.343	0.321
27	0.329	0.343	0.321
28	0.329	0.343	0.321
29	0.329	0.343	0.321
30	0.329	0.343	0.321
31	0.329	0.343	0.321
32	0.329	0.343	0.321
33	0.329	0.343	0.321
34	0.294	0.310	0.280
35	0.294	0.310	0.280
36	0.294	0.310	0.280
37	0.294	0.310	0.280
38	0.294	0.310	0.280
39	0.250	0.299	0.274
40	0.250	0.299	0.274
41	0.258	0.283	0.260
42	0.258	0.283	0.260
43	0.246	0.299	
44	0.246	0.299	
45		0.270	
46		0.270	
47			
48			
MEAN	0.326	0.332	0.306

CATHODIC PROTECTION DATA
MORTAR BLOCKS 50mA PER SQUARE METER (CM3)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

SLAB MS-2 REMOVED 05.02.86

HOLE	A	A	A	B	B
SLAB	MS-2	MS-2	MS-2	MS-2	MS-2
TIME	478			480	
DEPTH	03.02.86	06.10.86	29.11.86	05.02.86	07.11.86
0	0.210	0.182	0.183	0.151	0.141
1	0.210	0.182	0.183	0.151	0.141
2	0.318	0.113	0.282	0.338	0.311
3	0.318	0.113	0.282	0.338	0.311
4	0.327	0.288	0.326	0.337	0.320
5	0.327	0.288	0.326	0.337	0.320
6	0.327	0.288	0.326	0.337	0.320
7	0.327	0.288	0.326	0.337	0.320
8	0.327	0.288	0.326	0.337	0.320
9	0.327	0.288	0.326	0.337	0.320
10	0.327	0.288	0.326	0.337	0.320
11	0.327	0.288	0.326	0.337	0.320
12	0.327	0.288	0.326	0.337	0.320
13	0.327	0.288	0.326	0.337	0.320
14	0.312	0.285	0.321	0.327	0.317
15	0.312	0.285	0.321	0.327	0.317
16	0.312	0.285	0.321	0.327	0.317
17	0.312	0.285	0.321	0.327	0.317
18	0.312	0.285	0.321	0.327	0.317
19	0.312	0.285	0.321	0.327	0.317
20	0.312	0.285	0.321	0.327	0.317
21	0.312	0.285	0.321	0.327	0.317
22	0.312	0.285	0.321	0.327	0.317
23	0.312	0.285	0.321	0.327	0.317
24	0.255	0.266	0.254	0.304	0.286
25	0.255	0.266	0.254	0.304	0.286
26	0.255	0.266	0.254	0.304	0.286
27	0.255	0.266	0.254	0.304	0.286
28	0.255	0.266	0.254	0.304	0.286
29	0.255	0.266	0.254	0.304	0.286
30	0.255	0.266	0.254	0.304	0.286
31	0.255	0.266	0.254	0.304	0.286
32	0.255	0.266	0.254	0.304	0.286
33	0.255	0.266	0.254	0.304	0.286
34	0.204	0.247	0.253	0.276	0.261
35	0.204	0.247	0.253	0.276	0.261
36	0.204	0.247	0.253	0.276	0.261
37	0.204	0.247	0.253	0.276	0.261
38	0.204	0.247	0.253	0.276	0.261
39	0.170	0.242	0.245	0.250	0.259
40	0.170	0.242	0.245	0.250	0.259
41	0.168	0.227	0.209	0.220	0.257
42		0.227	0.209	0.220	0.257
43					
44					
45					
46					
47					
48					
MEAN	0.274	0.259	0.282	0.302	0.290

CATHODIC PROTECTION DATA
MORTAR BLOCKS 50mA PER SQUARE METER (CM3)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

SLAB MS-5 ON A	CURRENT DENSITY OF 1mA PER SQUARE METER FROM 14.02.86				
HOLE	A	A	B	B	B
SLAB	MS-5	MS-5	MS-5	MS-5	MS-5
TIME	481		482		
DEPTH	06.02.86	05.11.86	07.02.86	17.11.86	26.11.86
0	0.282	0.101	0.156	0.161	0.177
1	0.282	0.101	0.156	0.161	0.177
2	0.372	0.288	0.432	0.335	0.318
3	0.372	0.288	0.432	0.335	0.318
4	0.359	0.339	0.339	0.321	0.330
5	0.359	0.339	0.339	0.321	0.330
6	0.359	0.339	0.339	0.321	0.330
7	0.359	0.339	0.339	0.321	0.330
8	0.359	0.339	0.339	0.321	0.330
9	0.359	0.339	0.339	0.321	0.330
10	0.359	0.339	0.339	0.321	0.330
11	0.359	0.339	0.339	0.321	0.330
12	0.359	0.339	0.339	0.321	0.330
13	0.359	0.339	0.339	0.321	0.330
14	0.344	0.333	0.310	0.315	0.318
15	0.344	0.333	0.310	0.315	0.318
16	0.344	0.333	0.310	0.315	0.318
17	0.344	0.333	0.310	0.315	0.318
18	0.344	0.333	0.310	0.315	0.318
19	0.344	0.333	0.310	0.315	0.318
20	0.344	0.333	0.310	0.315	0.318
21	0.344	0.333	0.310	0.315	0.318
22	0.344	0.333	0.310	0.315	0.318
23	0.344	0.333	0.310	0.315	0.318
24	0.304	0.287	0.278	0.297	0.314
25	0.304	0.287	0.278	0.297	0.314
26	0.304	0.287	0.278	0.297	0.314
27	0.304	0.287	0.278	0.297	0.314
28	0.304	0.287	0.278	0.297	0.314
29	0.304	0.287	0.278	0.297	0.314
30	0.304	0.287	0.278	0.297	0.314
31	0.304	0.287	0.278	0.297	0.314
32	0.304	0.287	0.278	0.297	0.314
33	0.304	0.287	0.278	0.297	0.314
34	0.277	0.271	0.243	0.280	0.290
35	0.277	0.271	0.243	0.280	0.290
36	0.277	0.271	0.243	0.280	0.290
37	0.277	0.271	0.243	0.280	0.290
38	0.277	0.271	0.243	0.280	0.290
39	0.236	0.221	0.226	0.291	0.273
40	0.236	0.221	0.226	0.291	0.273
41	0.214	0.233	0.200	0.248	0.273
42	0.214	0.233	0.200	0.248	0.273
43	0.207		0.181		
44					
45					
46					
47					
48					
MEAN	0.315	0.294	0.289	0.284	0.292

CATHODIC PROTECTION DATA
CONCRETE BLOCKS 50mA PER SQUARE METER (AC1)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0	183	497
DEPTH	04.09.84	06.03.85	14.01.86
0	0.258	0.148	0.183
1	0.258	0.148	0.183
2	0.356	0.226	0.243
3	0.356	0.226	0.243
4	0.319	0.243	0.211
5	0.319	0.243	0.211
6	0.272	0.243	0.211
7	0.272	0.243	0.211
8	0.272	0.243	0.211
9	0.272	0.243	0.211
10	0.272	0.243	0.211
11	0.270	0.243	0.211
12	0.270	0.243	0.211
13	0.270	0.243	0.211
14	0.270	0.253	0.203
15	0.270	0.253	0.203
16	0.270	0.253	0.203
17	0.264	0.253	0.203
18	0.264	0.253	0.203
19	0.264	0.253	0.203
20	0.264	0.253	0.203
21	0.264	0.253	0.203
22	0.264	0.253	0.203
23	0.264	0.253	0.203
24	0.264	0.221	0.189
25	0.264	0.221	0.189
26	0.259	0.221	0.189
27	0.259	0.221	0.189
28	0.259	0.221	0.189
29	0.259	0.221	0.189
30	0.259	0.221	0.189
31	0.260	0.221	0.189
32	0.260	0.221	0.189
33	0.260	0.221	0.189
34	0.260	0.203	0.165
35	0.260	0.203	0.165
36	0.260	0.203	0.165
37	0.251	0.203	0.165
38	0.251	0.203	0.165
39	0.251	0.183	0.135
40	0.251	0.183	0.135
41	0.251	0.192	0.127
42	0.262	0.192	0.127
43	0.262	0.187	0.133
44	0.237	0.187	0.133
45	0.237		0.140
46	0.237		
47	0.240		
48	0.240		
49	0.234		
50	0.234		
MEAN	0.270	0.229	0.192

CATHODIC PROTECTION DATA
MORTAR BLOCKS 10mA PER SQUARE METER (DM5)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0	0	0	155	463
DEPTH	20.08.84	17.09.84	20.09.84	06.03.85	08.01.86
1	0.109	0.208	0.145	0.100	0.053
2	0.109	0.208	0.145	0.100	0.053
3	0.387	0.417	0.345	0.340	0.307
4	0.387	0.417	0.345	0.340	0.307
5	0.447	0.438	0.448	0.374	0.403
6	0.447	0.438	0.448	0.374	0.403
7	0.423	0.445	0.463	0.374	0.403
8	0.423	0.445	0.463	0.374	0.403
9	0.423	0.445	0.463	0.374	0.403
10	0.423	0.445	0.463	0.374	0.403
11	0.423	0.445	0.463	0.374	0.403
12	0.377	0.445	0.463	0.374	0.403
13	0.377	0.425	0.419	0.374	0.403
14	0.377	0.425	0.419	0.374	0.403
15	0.377	0.425	0.419	0.375	0.367
16	0.377	0.425	0.419	0.375	0.367
17	0.361	0.425	0.419	0.375	0.367
18	0.361	0.425	0.419	0.375	0.367
19	0.361	0.425	0.419	0.375	0.367
20	0.361	0.425	0.419	0.375	0.367
21	0.361	0.425	0.419	0.375	0.367
22	0.361	0.425	0.419	0.375	0.367
23	0.361	0.388	0.354	0.375	0.367
24	0.361	0.388	0.354	0.375	0.367
25	0.361	0.388	0.354	0.373	0.361
26	0.361	0.388	0.354	0.373	0.361
27	0.374	0.388	0.354	0.373	0.361
28	0.374	0.388	0.354	0.373	0.361
29	0.374	0.388	0.354	0.373	0.361
30	0.374	0.388	0.354	0.373	0.361
31	0.374	0.388	0.354	0.373	0.361
32	0.349	0.388	0.354	0.373	0.361
33	0.349	0.402	0.368	0.373	0.361
34	0.349	0.402	0.368	0.373	0.361
35	0.349	0.402	0.368	0.326	0.362
36	0.349	0.402	0.368	0.326	0.362
37	0.341	0.402	0.368	0.326	0.362
38	0.341	0.402	0.368	0.326	0.362
39	0.341	0.374	0.357	0.326	0.362
40	0.357	0.374	0.357	0.309	0.341
41	0.357	0.367	0.340	0.309	0.341
42	0.326	0.367	0.340	0.303	0.364
43	0.326	0.363	0.340	0.303	0.364
44	0.308	0.363	0.340	0.289	0.333
45	0.308	0.321	0.324	0.289	0.333
46			0.324		
47					
MEAN	0.358	0.397	0.376	0.345	0.354

CATHODIC PROTECTION DATA
CONCRETE SLABS 10mA PER SQUARE METER (BC2)
CONNECTED 2nd OCTOBER 1984
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0	0	0
DEPTH	02.10.84	02.10.84	17.01.86
1	0.173	0.152	0.125
2	0.233	0.237	0.125
3	0.240	0.217	0.294
4	0.240	0.217	0.294
5	0.269	0.269	0.245
6	0.269	0.269	0.245
7	0.269	0.269	0.245
8	0.310	0.299	0.245
9	0.310	0.299	0.245
10	0.310	0.299	0.245
11	0.310	0.299	0.245
12	0.310	0.299	0.245
13	0.282	0.283	0.245
14	0.282	0.283	0.245
15	0.282	0.283	0.279
16	0.282	0.283	0.279
17	0.282	0.283	0.279
18	0.282	0.283	0.279
19	0.282	0.283	0.279
20	0.296	0.279	0.279
21	0.296	0.279	0.279
22	0.296	0.279	0.279
23	0.296	0.279	0.279
24	0.296	0.279	0.279
25	0.296	0.279	0.252
26	0.296	0.279	0.252
27	0.296	0.279	0.252
28	0.239	0.258	0.252
29	0.239	0.258	0.252
30	0.239	0.258	0.252
31	0.239	0.258	0.252
32	0.239	0.258	0.252
33	0.239	0.258	0.252
34	0.239	0.258	0.252
35	0.229	0.237	0.238
36	0.229	0.237	0.238
37	0.229	0.237	0.238
38	0.229	0.237	0.238
39	0.229	0.237	0.238
40	0.229	0.228	0.255
41	0.229	0.228	0.255
42	0.240	0.221	0.231
43	0.240	0.221	0.231
44	0.231	0.229	0.250
45	0.231	0.229	0.250
46	0.246	0.242	0.243
47	0.246	0.242	0.243
48			
49			
50			
MEAN	0.262	0.259	0.250

CATHODIC PROTECTION DATA
MORTAR SLAB MS-17 - 222mA PER SQUARE METER
CONNECTED 17 JANUARY 1985
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0	1	4	11	36
DEPTH	14.01.85	18.01.85	21.01.85	28.01.85	22.02.85
0	0.070	0.064	0.069	0.077	0.043
1	0.070	0.064	0.069	0.077	0.043
2	0.346	0.353	0.331	0.245	0.383
3	0.346	0.353	0.331	0.245	0.383
4	0.456	0.421	0.404	0.385	0.358
5	0.456	0.421	0.404	0.385	0.358
6	0.456	0.421	0.404	0.385	0.358
7	0.456	0.421	0.404	0.385	0.358
8	0.456	0.421	0.404	0.385	0.358
9	0.456	0.421	0.404	0.385	0.358
10	0.456	0.421	0.404	0.385	0.358
11	0.456	0.421	0.404	0.385	0.358
12	0.456	0.421	0.404	0.385	0.358
13	0.456	0.421	0.404	0.385	0.358
14	0.410	0.388	0.417	0.364	0.336
15	0.410	0.388	0.417	0.364	0.336
16	0.410	0.388	0.417	0.364	0.336
17	0.410	0.388	0.417	0.364	0.336
18	0.410	0.388	0.417	0.364	0.336
19	0.410	0.388	0.417	0.364	0.336
20	0.410	0.388	0.417	0.364	0.336
21	0.410	0.388	0.417	0.364	0.336
22	0.410	0.388	0.417	0.364	0.336
23	0.410	0.388	0.417	0.364	0.336
24	0.376	0.374	0.388	0.348	0.339
25	0.376	0.374	0.388	0.348	0.339
26	0.376	0.374	0.388	0.348	0.339
27	0.376	0.374	0.388	0.348	0.339
28	0.376	0.374	0.388	0.348	0.339
29	0.374	0.371	0.361	0.362	0.343
30	0.374	0.371	0.361	0.362	0.343
31	0.374	0.371	0.361	0.362	0.343
32	0.374	0.371	0.361	0.362	0.343
33	0.374	0.371	0.361	0.362	0.343
34	0.374	0.356	0.369	0.354	0.254
35	0.374	0.356	0.369	0.354	0.254
36	0.274	0.356	0.369	0.354	0.254
37	0.274	0.356	0.369	0.354	0.254
38	0.274	0.356	0.369	0.354	0.254
39	0.274	0.371	0.381	0.309	0.230
40	0.274	0.371	0.381	0.309	0.230
41	0.274	0.352	0.381	0.312	0.195
42	0.274	0.352	0.317	0.312	0.195
43	0.293	0.323	0.317	0.236	0.147
44	0.293	0.323	0.317	0.236	0.147
45			0.256		
46					
47					
48					
49					
MEAN	0.367	0.367	0.368	0.337	0.303

CATHODIC PROTECTION DATA
MORTAR SLAB MS-17 - 222mA PER SQUARE METER
CONNECTED 17 JANUARY 1985
CHLORIDE LEVELS AS A FUNCTION OF TIME

BETWEEN REBARS

TIME		0	74	110	118	354
DEPTH		14.01.85	02.04.85	07.05.85	15.05.85	06.01.86
	0	0.070	0.072	0.092	0.048	0.127
	1	0.070	0.072	0.092	0.048	0.127
	2	0.346	0.250	0.210	0.194	0.114
	3	0.346	0.250	0.210	0.194	0.114
	4	0.456	0.321	0.306	0.310	0.263
	5	0.456	0.321	0.306	0.310	0.263
	6	0.456	0.321	0.306	0.310	0.263
	7	0.456	0.321	0.306	0.310	0.263
	8	0.456	0.321	0.306	0.310	0.263
	9	0.456	0.321	0.306	0.310	0.263
	10	0.456	0.321	0.306	0.310	0.263
	11	0.456	0.321	0.306	0.310	0.263
	12	0.456	0.321	0.306	0.310	0.263
	13	0.456	0.321	0.306	0.310	0.263
	14	0.410	0.320	0.317	0.282	0.225
	15	0.410	0.320	0.317	0.282	0.225
	16	0.410	0.320	0.317	0.282	0.225
	17	0.410	0.320	0.317	0.282	0.225
	18	0.410	0.320	0.317	0.282	0.225
	19	0.410	0.320	0.317	0.282	0.225
	20	0.410	0.320	0.317	0.282	0.225
	21	0.410	0.320	0.317	0.282	0.225
	22	0.410	0.320	0.317	0.282	0.225
	23	0.410	0.320	0.317	0.282	0.225
	24	0.376	0.279	0.321	0.257	0.199
	25	0.376	0.279	0.321	0.257	0.199
	26	0.376	0.279	0.321	0.257	0.199
	27	0.376	0.279	0.321	0.257	0.199
	28	0.376	0.279	0.321	0.257	0.199
	29	0.374	0.279	0.321	0.257	0.199
	30	0.374	0.279	0.321	0.257	0.199
	31	0.374	0.279	0.321	0.257	0.199
	32	0.374	0.279	0.321	0.257	0.199
	33	0.374	0.279	0.321	0.257	0.199
	34	0.374	0.246	0.321	0.197	0.139
	35	0.374	0.246	0.321	0.197	0.139
	36	0.274	0.246	0.321	0.197	0.139
	37	0.274	0.246	0.321	0.197	0.139
	38	0.274	0.246	0.321	0.197	0.139
	39	0.274	0.209	0.326	0.159	0.155
	40	0.274	0.209	0.326	0.159	0.155
	41	0.274	0.203	0.315	0.132	0.116
	42	0.274	0.203	0.315	0.132	0.116
	43	0.292	0.169	0.274	0.115	0.101
	44	0.292	0.169	0.274	0.115	0.101
	45		0.155	0.289		0.103
	46		0.155	0.289		0.103
	47		0.112	0.294		0.094
	48		0.112	0.294		0.094
	49			0.280		
MEAN		0.366	0.261	0.299	0.239	0.187

CATHODIC PROTECTION DATA
MORTAR SLABS 10mA PER SQUARE METER (FM4)
CONNECTED 24 MARCH 1985
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0	0	0	0	258	487
DEPTH	16.08.84	22.08.84	10.09.84	26.09.84	10.06.85	24.01.86
1	0.147	0.192	0.145	0.105	0.246	0.047
2	0.147	0.192	0.145	0.105	0.246	0.047
3	0.319	0.417	0.332	0.368	0.273	0.282
4	0.319	0.417	0.332	0.368	0.273	0.282
5	0.425	0.423	0.414	0.427	0.384	0.394
6	0.425	0.423	0.414	0.427	0.384	0.394
7	0.394	0.366	0.367	0.415	0.384	0.394
8	0.394	0.366	0.367	0.415	0.384	0.394
9	0.394	0.366	0.367	0.415	0.384	0.394
10	0.394	0.366	0.367	0.415	0.384	0.394
11	0.394	0.366	0.367	0.415	0.384	0.394
12	0.334	0.366	0.367	0.415	0.384	0.394
13	0.334	0.363	0.352	0.379	0.384	0.394
14	0.334	0.363	0.352	0.379	0.384	0.394
15	0.334	0.363	0.352	0.379	0.392	0.369
16	0.334	0.363	0.352	0.379	0.392	0.369
17	0.339	0.338	0.352	0.379	0.392	0.369
18	0.339	0.338	0.352	0.379	0.392	0.369
19	0.339	0.338	0.352	0.379	0.392	0.369
20	0.339	0.338	0.352	0.379	0.392	0.369
21	0.339	0.338	0.352	0.379	0.392	0.369
22	0.339	0.338	0.352	0.379	0.392	0.369
23	0.339	0.338	0.340	0.350	0.392	0.369
24	0.339	0.338	0.340	0.350	0.392	0.369
25	0.339	0.338	0.340	0.350	0.357	0.355
26	0.339	0.338	0.340	0.350	0.357	0.355
27	0.310	0.337	0.340	0.350	0.357	0.355
28	0.310	0.337	0.340	0.350	0.357	0.355
29	0.310	0.337	0.340	0.350	0.357	0.355
30	0.310	0.337	0.340	0.350	0.357	0.355
31	0.310	0.337	0.340	0.350	0.357	0.355
32	0.326	0.340	0.340	0.350	0.357	0.355
33	0.326	0.340	0.329	0.326	0.357	0.355
34	0.326	0.340	0.329	0.326	0.357	0.355
35	0.326	0.340	0.329	0.326	0.327	0.324
36	0.326	0.340	0.329	0.326	0.327	0.324
37	0.322	0.340	0.329	0.326	0.327	0.324
38	0.322	0.334	0.329	0.326	0.327	0.324
39	0.322	0.334	0.311	0.326	0.327	0.324
40	0.358	0.334	0.311	0.326	0.303	0.279
41	0.358	0.334	0.306	0.326	0.303	0.279
42	0.358	0.340	0.306	0.326	0.298	0.276
43	0.360	0.340	0.298	0.302	0.298	0.276
44	0.360	0.330	0.298	0.302	0.292	0.280
45	0.271	0.330	0.298			0.280
46		0.303	0.273			0.255
47		0.303	0.273			
48						
49						
50						
MEAN	0.334	0.343	0.331	0.351	0.352	0.334

CATHODIC PROTECTION DATA
CONCRETE SLABS 10mA PER SQUARE METER (EC1.EC2)
CONNECTED 24 MARCH 1985
CHLORIDE LEVELS AS A FUNCTION OF TIME

TIME	0
DEPTH	04.09.84
1	0.258
2	0.258
3	0.356
4	0.356
5	0.319
6	0.319
7	0.272
8	0.272
9	0.272
10	0.272
11	0.272
12	0.270
13	0.270
14	0.270
15	0.270
16	0.270
17	0.270
18	0.264
19	0.264
20	0.264
21	0.264
22	0.264
23	0.264
24	0.264
25	0.264
26	0.264
27	0.259
28	0.259
29	0.259
30	0.259
31	0.259
32	0.260
33	0.260
34	0.260
35	0.260
36	0.260
37	0.260
38	0.251
39	0.251
40	0.251
41	0.251
42	0.251
43	0.262
44	0.262
45	0.237
46	0.237
47	0.237
48	0.240
49	0.240
50	0.234
51	0.234
MEAN	0.265

APPENDIX 2

SAMPLE CALCULATION OF CURRENT EFFICIENCY

Loss of chloride from the system can be explained in terms of the charge transfer reaction taking place at the anode:

$$2\ Cl^- \longrightarrow Cl_2 + 2\ e$$

If the sole anode reaction was the oxidation of chloride ion, then the mass of chloride consumed can be calculated from the number of coulombs of electricity used in the experiment. For slab MS-17 ($0.09m^2$) which operated using a current density of 222 mA m^{-2} for 74 days, the total number of faradays used is given by:

$$\frac{222 \times 0.09}{1000} \times \frac{74 \times 24 \times 60 \times 60}{96{,}485} = 1.32\ F$$

This is equivalent to 46.79g. of chlorine.

The amount of chlorine actually removed from the slabs can be obtained from the experimentally measured decrease in the chloride concentration. For MS-17 operated for 74 days the mean chloride concentration fell from 0.367% to 0.261% assuming that the profiles are consistent over the whole cross-section of the slab. The loss of chlorine can be calculated based on a depth of 4.4cm. from the surface to the rebar and a density of $2.2g.cm^{-3}$. The mass of the chloride contaminated concrete is therefore

$$30 \times 30 \times 4.4 \times 2.2 = 8712g.$$

and gives the mass of chlorine removed as

$$8712 \times \frac{(0.367 - 0.261)}{100} = 9.23g.\ \text{of chlorine.}$$

Therefore the current efficiency is $\frac{9.23}{46.79} \times 100 = 19.7\%$

If it is assumed that the decrease in the chloride concentration is exaggerated by 54.5% because the measurements were taken directly over the rebars, then the current efficiency will be reduced to 10.7%.